Wood Contract No:	7650
Client Name:	INEOS
Project Title:	Project One
Project Location:	Antwerp, Belgium

Revision	**A4**	**Signature**	**A5**	**Signature**	**A6**	**Signature**
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CONTENTS

Section	Summary of Change	Revision
5	Correction to note for acoustic insulation in Table 1. Acoustic to be over cold insulation not under.	A4
5	Additional note added to acoustic insulation, detailing how thickness on P&ID should be interpreted.	A4
5	Correction to AS, BS, CS in Table 2	A4
6.4	Additional detail prescribing where tie-wire may be used for jacketing	A4
6.4	Information added about sealing compounds	A4
7.1	Correction for flangebelt interface with flanges.	A4
7.1	Additional information about when flangebelts shall be prescribed	A4
7.3	Line stating that mineral fibre insulation is the default material for hot insulation has been removed.	A4
7.5	Section added for alternative materials, including Aerogel	A4
7.6 (was 7.5)	Required clearance beneath pipe shoes increased from 25mm to 50mm	A4
7.6 (was 7.5)	Detail about drain hole drilling direction added	A4
7.6 (was 7.5)	Detail about protection of electric tracing cables with grommets added	A4
7.7 (was 7.6)	All bottom heads of insulated vessels to be insulated – Not diameter dependent	A4
7.7 (was 7.6)	Additional detail on designing for temperature at equipment support interface	A4
7.7 (was 7.6)	Clarification added for use of thickness tables for Equipment	A4
7.8.1 (was 7.7.1)	Clarification added to table headers/rows of Table 5	A4
7.8.1 (was 7.7.1)	Additional Table 6 added for Pyrogel thicknesses	A4
7.8.2 (was 7.7.2)	Clarification added to table headers/rows of Table 7 (was 6)	A4
8.1	Added detail about preventing damage to vapour barrier	A4
8.1	Additional information about when flangebelts shall be prescribed	A4
8.7	Section added for alternative materials, including Aerogel	A4
8.8 (was 8.7)	Changed wording to state that pipe support shall be attached to outside of insulation.	A4
8.9 (was 8.8)	Insulation by hardwood blocks deleted	A4
8.9 (was 8.8)	Additional detail on designing for temperature at equipment support interface, and use of insulation materials	A4
8.10 (was 8.9)	Clarification added for use of thickness tables for Equipment	A4
8.10.1 (was 8.9.1)	Clarification added to table headers/rows of Table 10 (was 9)	A4
8.10.1 (was 8.9.1)	Additional Table 11 added for Cryogel Z thicknesses	A4
9.1	Changed wording from where ‘specified’ to where ‘required’…	A4
9.1	Added statement that the installation must comply with CINI	A4
1	Dual service added.	A5
2	Deleted reference to Table 1 and Table 2 with respect to insulation codes used on flow diagrams and line lists.	A5
4	European Standards already referenced in body of specification added to list. 7650-8820-PR-100-0004 – Equipment Numbering Procedure added to list.	A5
5	Table 1 and Table 2 replaced.	A5
6.4	Requirements for sealing compound consolidated for clarity.	A5
6.6	Corrosion protection system selection reference updated from CINI to 7650-8440-SP-100-0002	A5

Section	Summary of Change	Revision
7.1	Corrosion (painting) system selection reference to 7650-8440-SP-100-0002 added.	A5
7.3	Mineral wool water-repellent standards updated to latest standards.	A5
7.4	Sentence amended to state silicate material shall be below subsequent layers of mineral wool insulation.	A5
7.5	Applications for aerogel insulation updated.	A5
7.7	Para.2 amended to clarify bottom heads of all insulated vessels require insulating.	A5
7.7	Para.6 amended for shear induced during expansion movement.	A5
7.7	Para.8 Sentence amended to “Insulation shall not be applied to the following unless required for…”	A5
7.8	Sentence deleted re. verification of thicknesses for specific manufacturers.	A5
7.8	Table 5, Table 6, Table 7 design parameter table update to format only.	A5
8.1	Corrosion (painting) system selection reference to 7650-8440-SP-100-0002 added. Minor typo correction to Para. 4.	A5
8.4	Use of PIR for dual temperature service for operating temperatures up to 90°C deleted.	A5
8.5	Limitation of cellular glass only to temperatures exceeding 90°C removed.	A5
8.5	Table 9, addition K valued added for 430°C. Option for alternative materials removed.	A5
8.7	Applications for aerogel insulation updated.	A5
8.9	Para.8 and Para.9 revised completely for improved clarity of requirements only.	A5
8.10	Table 10, Table 11 design parameter table update to format only	A5
8.11	New section added	A5
8.11	Table 12, new dual service added	A5
9.2	“Example” deleted from column header for thickness of sheet.	A5
9.3	Requirement for IPMT approval of proprietary combined thermal/acoustic systems added.	A5
10	Material description in Table 14 (previously Table 13) updated	A5
5.1. & 5.2.	Update insulation coding system implementing Cryogenic Spill Protection (CSP) and combinations of CSP with Jet and/or Pool fire.	A6
7	Update insulation thickness tables adding size 42”	A6
8	Update insulation thickness tables adding size 42”	A6

1. PURPOSE

This standard covers the use of hot, cold and dual service thermal insulation for above ground, external insulation of engineered piping and equipment, including pressure vessels and circular ducting, heat exchangers, mechanical equipment, and packages on INEOS Project One located in Antwerp, Belgium.

This standard does not cover insulated underground lines, nor vendor designed insulation for boiler or fired heater packages including air-heaters, economisers, gas flues and air ducting. This standard does not cover vendor designed insulation for refrigeration packages including cryogenic pumps, compressors, and tanks.

2. SCOPE

The insulation requirements of this standard are suitable for use in both indoor and outdoor service with normal process plant atmospheres. Alternative designs and materials shall be considered if necessary for coastal environment atmospheres or potential leaks and spills of chemicals.

Deviations to this specification and/or use of vendor standards shall be submitted for review and approval by IPMT.

Hot service insulation refers to insulation of piping and equipment operating between ambient temperature and 800°C, for heat conservation, process stabilisation, temperature maintenance, winterisation, and personnel and fire protection. Insulation for temperatures above 550°C shall be subject to individual consideration by IPMT. Hot service insulation requirements are detailed in Section 7.

Cold service insulation refers to insulation of piping and equipment operating between minus 196°C and ambient, for reduction of heat gain, process stabilisation, and the prevention of frost and condensate accumulation. Cold service insulation requirements are detailed in Section 8; also applicable for dual-service insulation.

Items emitting unacceptable levels of noise shall be subject to acoustic attenuation insulation. This may be in addition to insulation specified for other purposes. Acoustic insulation requirements are detailed in Section 9.

Piping and equipment requiring insulation shall be specified on the following documents:

1. P&IDs
2. Engineering flow diagrams and line lists
3. Piping general arrangements and isometrics
4. Instrument piping details and schedules
5. Vessel and exchanger drawings and insulation schedules
6. Equipment vendor’s general arrangement drawings

Piping and equipment shall be insulated with the thickness of insulation appropriate to the classification and operating temperature.

Instruments and associated piping subject to operating flow and/or temperature conditions approximating those in the piping or equipment to which they are connected shall be insulated to the same requirements as that piping or equipment.

3. TERMINOLOGY

The following terms are used throughout the document:

Item	Definition
May	A permissive statement; an option neither mandatory nor specifically recommended
Shall	Designates a requirement which is mandatory. Deviation will require approval via the formal process noted in (7650-8820-PR-100-0030).
Should	A specific recommendation where conformance is not mandatory

4. REFERENCE DOCUMENTS

The following standards shall apply as relevant:

Document Number	Title
CINI – International Standard for Industrial Insulation	
CINI (Latest, 2018)	CINI Digital Manual (Latest, 2018)
API – American Petroleum Institute	
API 583	Corrosion Under Insulation and Fireproofing
ASTM International	
ASTM C-547	Standard Specification for Mineral Pipe Insulation
ASTM C-553	Standard Specifications for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM C-585	Standard Practice of Inner and Outer Dimension of Thermal Insulation for Nominal Sizes of Pipe and Tubing
ASTM C-591	Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
ASTM C-612	Standard Specification for Mineral Fiber Block and Board Thermal Insulation
ASTM C-795	Thermal Insulation for Use in Contact with Austenitic Stainless Steel
ASTM C-1029	Standard Specification for Spray-Applied Rigid Cellular Polyurethane Thermal Insulation
ASTM C-1728	Standard Specification for Flexible Aerogel Insulation
ISO - International Organisation for Standardisation	
ISO 12241:2008	Thermal Insulation for Building Equipment and Industrial Installations – Calculation Rules
ISO 15665	Acoustics – Acoustic Insulation for pipes, valves, and flanges
EN – European Standards	
NBN EN-13472	Thermal insulating products for building equipment and industrial installations - Determination of short term water absorption by partial immersion of preformed pipe insulation
NBN EN ISO 29767	Thermal insulating products for building applications - Determination of short-term water absorption by partial immersion

The following project standards shall apply as relevant:

Document Number	Title
Basic Engineer Design Data:	
7650-8820-SP-100-0001	Basic Engineering Design Data
Technology:	
7650-8440-SP-100-0002	Protective Paint and Coatings
7650-8440-SP-100-0003	External Fireproofing of Equipment and Supports

The following project procedures shall apply as relevant:

Document Number	Title
7650-8640-PR-100-0002	Procurement quality surveillance procedure
7650-8640-PR-100-0003	Surveillance Grades and Inspection
7650-8650-PR-100-0001	Preservation, packing & marking procedure
7650-8820-PR-100-0004	Equipment Numbering Procedure
7650-8820-PR-100-0005	CE Marking Procedure
7650-8820-PR-100-0012	Compliance and Conformity Procedure
7650-8820-PR-100-0030	Technical Queries and Waiver Requests

The following project standard drawings shall apply as relevant:

Document Number	Title
7650-8430-19-100-0003	Support Skirt Detail
7650-8430-19-100-0012	Vertical Vessel - Insulation and Fireproofing Supports
7650-8430-19-100-0013	Horizontal Vessel Insulation Supports
7650-8430-19-100-0014	Vertical Vessels Cold Insulation Supports
7650-8430-19-100-0015	Horizontal Vessel Cold Insulation Supports
7650-8430-19-100-0022	Earthing Lugs
7650-8430-19-100-0026	Saddle Details
7650-8430-19-100-0027	Support Legs for Vertical Drums
7650-8430-19-100-0028	Supports for Horizontal Shell and Tube Heat Exchangers
7650-8430-19-100-0029	Supports for Vertical Shell and Tube Heat Exchangers
7650-8430-19-100-0034	Bracket Details for Equipment Nameplates

5. SYMBOLOGY AND CLASSIFICATION

5.1 Table 1: Insulation Symbology, Classification and General Conditions of Use

PRIMARY CODE	CLASSIFICATION	SECONDARY CODE	MATERIALS	TEMPERATURE	CLADDING	NSULATION THICKNESS TABLE NO.	INSULATION THICKNESS SELECTION CRITERIA	COMMENTS
HOT INSULATION								
H	Heat Conservation (Process lines)	m	Mineral wool	Amb to <550	Aluzinc	Table 5	Normal operating temp of process fluid and nominal pipe size	Each section of the equipment having defined sections operating at differing temperatures may be insulated to suit its individual temperature. For shell and tube exchanger shells and channels, use the higher of the inlet and outlet temperatures.
		e	Alkaline Earth Silicate Wool	>500		Note 1		
		d	Alkaline Earth Silicate Wool + Mineral wool			Note 1		
		r	Silica Aerogel	<650		Table 6		
		a	Mineral wool	Amb to <550	SS	Table 5		
		b	Alkaline Earth Silicate Wool	>500		Note 1		
		c	Alkaline Earth Silicate Wool + Mineral wool			Note 1		
		f	Silica Aerogel	<650		Table 6		
		h	Custom combination			Special consideration	Special consideration	Piping and equipment subject to special considerations to determine insulation thickness and design, which shall be clearly indicated on the engineering flow diagrams and line lists.
P	Personnel Protection (Insulated or Stood-Off Guards)	m	Mineral wool	<550	Aluzinc	Table 7	Normal operating temp of process fluid and nominal pipe size	Over unlined piping and equipment insulate or provide open mesh metal guards on operating plant which would normally be left uninsulated and which may be accessible during the performance of routine duties by operating personnel.
		a	Mineral wool	<550	SS	Table 7		
		g	Stood off guards	N/A	N/A	N/A		
CYCLIC/DUAL SERVICE INSULATION								
Y	Cyclic/Dual Service	w	Cellular glass	-180 to 450	SS	Table 12	Normal operating temp of process fluid and nominal pipe size	Each section of the equipment having defined sections operating at differing temperatures may be insulated to suit its individual temperature. For shell and tube exchanger shells and channels, use the higher of the inlet and outlet temperatures.

Table 1 (continued)

PRIMARY CODE	CLASSIFICATION	SECONDARY CODE	MATERIALS	TEMPERATURE	CLADDING	NSULATION THICKNESS TABLE NO.	INSULATION THICKNESS SELECTION CRITERIA	COMMENTS
COLD INSULATION								
G	Prevention of heat gain and condensation control (Process lines)	p	Phenolic Foam		Aluzinc	Note 2	Normal operating temp of process fluid and nominal pipe size	Each defined section of piping and equipment operating at different temperatures may be insulated to suit its individual temperature. For shell and tube exchanger shells and channel use the lower of the inlet and outlet temperatures.
		t	Poly-Iso-Cyanurate	-180 to 100		Table 10		
		u	Cellular Glass	-180 to 450		Note 2		
		j	Foamed EPDM Rubber	<90		Note 2		
		x	Silica Aerogel	-180 to 125		Table 11		
		n	Phenolic Foam		SS	Note 2		
		y	Poly-Iso-Cyanurate	-180 to 100		Table 10		
		q	Cellular Glass	-180 to 450		Note 2		
		s	Foamed EPDM Rubber	<90		Note 2		
		v	Silica Aerogel	-180 to 125		Table 11		
		z	Custom combination			Special consideration	Special consideration	Piping and equipment subject to special considerations to determine insulation thickness and design, which shall be clearly indicated on the engineering flow diagrams and line lists.
NO INSULATION								
N	Not insulated	Blank	N/A					

Table 1 (continued)

PRIMARY / TERTIARY CODE	CLASSIFICATION	SECONDARY CODE	MATERIALS	TEMPERATURE	CLADDING	NSULATION THICKNESS TABLE NO.	INSULATION THICKNESS SELECTION CRITERIA	COMMENTS
ACOUSTIC INSULATION								
A	Acoustic A	Blank	Semi rigid mineral fibre	N/A	0.6mm SS plate	Table 13	Acoustic category attenuation subject to calculated insertion loss requirements	For cold service, acoustic insulation shall be applied over cold service insulation system to achieve attenuation. The thickness specified on the P&ID should be the total thickness required (inclusive of acoustic insulation). - For hot: See 9.3.1 - For cold: See 9.3.2
B	Acoustic B	Blank	Semi rigid mineral fibre	N/A	0.8mm SS plate			
C	Acoustic C	Blank	Dual layer Semi rigid mineral fibre	N/A	0.7 + 0.7 mm SS plate			
E	Acoustic (A,B,C) + Pool Fire	f	Silica Aerogel	<650	SS	Note 3	Thickness is subject to calculated PFP/CSP duration and insertion loss requirements	To be used for parts where Acoustic insulation is required with a combination of Jet, Pool and/or CSP. Individual requirements for the particular insulation purpose shall be clearly indicated on the engineering flow diagrams and line lists.
		v		-180 to 125				
L	Acoustic (A,B,C) + Jet Fire	f		<650				
		v		-180 to 125				
Z	Acoustic (A,B,C) + Jet/Pool	f		<650				
		v		-180 to 125				
O	Acoustic (A,B,C) + CSP	f		<650				
		v		-180 to 125				
U	Acoustic (A,B,C) + CSP/Jet/Pool	f		<650				
		v		-180 to 125				
PASSIVE FIRE PROTECTION (PFP) AND CRYOGENIC SPILL PROTECTION (CSP)								
F	Pool Fire	w	Cellular glass	<650	SS	Note 3	Protection thickness is subject to calculated duration requirements	Particular requirements for Jet, Pool and/or CSP shall be clearly indicated on the engineering flow diagrams and line lists.
		f	Silica Aerogel	<650	SS			
J	Jet Fire	w	Cellular glass	-180 to 450	SS			
		f	Silica Aerogel	<650	SS			
V	Jet + Pool Fire	w	Cellular glass	-180 to 450	SS			
		f	Silica Aerogel	<650	SS			
S	Cryogenic Spill Protection	w	Cellular glass	-180 to 450	SS			
		f	Silica Aerogel	<650	SS			
T	CSP/Jet/Pool	w	Cellular glass	-180 to 450	SS			
		f	Silica Aerogel	<650	SS			

Table 1 – Symbology, Classification, and General Conditions of Use

Notes

General: The codes and classifications listed above are to be used in the piping tag numbers, in the format according to the Project Equipment Numbering Procedure (7650-8820-PR-100-0004), and other deliverables which show the insulation designation for piping or equipment.

Note 1 : Contractor shall calculate required thickness based on thermal parameters of the specific product, using the general parameters of table 5 / table 6

Note 2 : Contractor shall calculate required thickness based on thermal parameters of the specific product, using the general parameters of table 10 / table 11

Note 3 : Any combination of Hot, Cold, Acoustic, Jet, Pool and/or CSP requires particular thickness calculation that makes part of final documentation

Examples of application of Insulation
Codes :

		no PFP no CSP	Pool Fire	Jet Fire	Pool and Jet	CSP	Pool/Jet + CSP
Not insulated	**Ins Code**	**N**	**F**	**J**	**V**	**S**	**T**
	Material (I)	n/a	w, f	w, f	w, f	w, f	w, f
Hot Insulation	**Ins Code**	**H.**	**H.F**	**H.J**	**H.V**	**H.S**	**H.T**
	Material (I)	m,... (II)	w, f	w, f	w, f	f	f
Cold Insulation	**Ins Code**	**G.**	**G.F**	**G.J**	**G.V**	**G.S**	**G.T**
	Material (I)	p,... (II)	q, v	q, v	q, v	v	v
Personnel Protection	**Ins Code**	**P.**	**P.F**	**P.J**	**P.V**	**P.S**	**P.T**
	Material (I)	m, a, g	w, f	w, f	w, f	f	f
Acoustic	**Ins Code**	**A,B,C**	**E.**	**L.**	**Z.**	**O.**	**U.**
	Material (I)	(III)	f, v	f, v	f, v	f, v	f, v
Hot Insulation + Acoustic	**Ins Code**	**H.(A,B,C)**	**H.E**	**H.L**	**H.Z**	**H.O**	**H.U**
	Material (I)	m,... (II)	f	f	f	f	f
Cold Insulation + Acoustic	**Ins Code**	**G.(A,B,C)**	**G.E**	**G.L**	**G.Z**	**G.O**	**G.U**
	Material (I)	p,... (II)	v	v	v	v	v
Electrical Tracing	**Ins Code**	**H.-ET**	**H.F-ET**	**H.J-ET**	**H.V-ET**	**H.S-ET**	**H.T-ET**
	Material (I)	m,...	w, f	w, f	w, f	f	f

Note (I) : this is the secondary code that will appear at the "." in the Ins Code above
Note (II) : all possible materials/secondary codes as per § 5.1 and §5.2.
Note (III) : A,B,C can be Primary or Tertiary Code if combined with Hot/Cold insulation

Examples of complete codes :

Hm100 : Heat conservation 100 mm mineral wool with Aluzinc cladding
HaB200 : Heat conservation 200 mm mineral wool + Acoustic B with SS cladding
HfL120 : Heat conservation 120 mm silica aerogel with acoustic insul and jet fire, SS cladding
GvT95 : Cold insul 95 mm silica aerogel with CSP, Jet and Pool fire protection, SS cladding

5.2 Table 2: Steam and Electric Tracing Symbology and Classification

CODE	CLASSIFICATION	SECONDARY CODE	MATERIALS	TEMPERATURE	CLADDING	NSULATION THICKNESS TABLE NO.	INSULATION THICKNESS SELECTION CRITERIA	COMMENTS
ST	Steam Tracing (inc. Winterisation)	n/a	n/a	n/a	n/a	Table 5 / Table 6	Normal operating temp of process fluid and on pipe size greater than parent pipe	Insulation where operating plant requires a protective heating system to protect piping, equipment, and instruments against the effects of ambient temperatures. (including hydrate formation, condensation, viscosity change, and pour point suppression).
ET	Electric Tracing	n/a	n/a	n/a	n/a	Table 5/ Table 6	Normal operating temp of process fluid and on pipe size greater than parent pipe	Insulation where operating plant requires a protective heating system to protect piping, equipment, and instruments against the effects of ambient temperatures. (including hydrate formation, condensation, viscosity change, and pour point suppression).

Table 2 – Steam and Electric Tracing

6. GENERAL

6.1 Materials

All materials provided shall be appropriate for the intended use and shall be new, and of high quality and good appearance. Wet or damaged insulation shall not be used in any circumstance.

Insulation materials shall have a proven history operating in the required conditions and shall be sourced from reputable vendor.

Insulation materials shall be chemically inert, non-sulphurous, rot-proof, vermin-proof, non-injurious to health, and non-corrosive to steel or aluminium.

Insulation materials containing asbestos in any form are not permitted. Any additional local restrictions on material usage must also be adhered to.

All materials shall be non-combustible. In addition, insulation and jacketing materials backed with paper or other flammable materials shall not be used.

Zinc bearing materials shall not be used on stainless steel piping or equipment.

6.2 Clearances

Piping and equipment shall be designed to provide an absolute minimum clearance of 50mm between the outside surface of any insulation finishing material and any obstruction such as structural steel, electrical conduit, piping, or other insulated lines, in both the ambient and the operating condition. Where possible, 100mm clearance is required between cold insulation and any other adjacent item to facilitate the installation of vapour barriers. Pipe spacing must also allow for the inclusion of contraction joints when included in parallel pipe runs.

6.3 Installation Details

Each insulation system identified in Table 1 requires different details for each installation, based on the insulation type, equipment, local detail, and the objective of the system.

The installation shall be in accordance with CINI, which includes the industry minimum requirements for each installation detail.

A competant applicator shall be employed for the installation, and they shall bear the responsibility for installing the system in such a way as to provide satisfactory operational performance through the design life of the system. The applicator shall work to produce the minimum of waste and debris, and the final job shall present a neat and efficient installation.

The applicator shall not carry out any welding or drilling on piping or equipment. He shall however be responsible to carry out a check and confirm that all insulation supports, as indicated on the fabrication drawings, have been appropriately installed, and are sufficient for the planned insulation installation.

6.4 Weatherproof Jacketing

Jacketing shall be installed around all insulation systems to offer protection from weather and other damage mechanisms. Jacketing shall be supplied in accordance with CINI (3.1), which includes installation specifics based on the design and application.

Aluzinc jacketing (e.g. Sendzimir) shall be used with the exception of fire hazard protection or lines having design temperature above 600°C, which require the use of stainless steel. Stainless steel jacketing shall be flat mill finished grade 2B, ASTM A240 Gr 304 or 316.

Binding, tie-wire (for the mat material only, not jacketing), and banding used to secure jacketing (and sacrificial foil systems) shall be 18Cr-8Ni fully annealed stainless steel. Wire shall be minimum 1.22mm diameter. Banding shall be 0.5mm thick, 12mm wide for piping, and 20mm wide for equipment, cut to required lengths at site. Banding clips used to secure the bands shall

be supplied in a matching specification for the parent material; as shall expansion sections of banding when they are required.

All jacketing shall be designed and installed to naturally shed water at all times. All surfaces shall be sloped to allow water to drain freely - Flat horizontal surfaces or areas where water could accumulate are not acceptable. Jacketing shall be overlapped and secured with screws or rivets, and sealed using a suitable metal sealant..

All equipment projections such as nozzles shall have the jacketing sealed using a metal flashing cut to fit the projection and extend over the jacketing a minimum of 75mm, made watertight using self-tapping screws or rivets and metal sealant.

Sealing compound shall be a flexible non-setting silicone based type, free from acetic acid, , having properties which render materials waterproof, weatherproof, frost proof, UV resistant, and chemical and fire resistant.

Sealing compound shall be used for sealing where there is a risk of water entrainment that cannot be avoided with proper design of the joint or in the case of sealing plates and/or insulations collars will not give sufficient weather protection results. Use of sealing compounds shall be used in such a manner that it is protected from atmospheric contact, as much as possible.

Covering joints shall be sealed with sealing compound in cases including but not limited to:

- Object is exposed to gravity water
- Underneath T-pieces
- Fixing lugs through insulation covering
- Vertical and horizontal nozzles of equipment and vessels
- Objects specified separately in job description and contract
- Lifting lugs to be fully insulated and marked

6.5 Inspection

The insulation system shall be inspected in accordance with project and equipment specific inspection criteria. Inspection shall be included at the following stages as a minimum:

1. At receipt of materials
2. Before and during application of insulation system
3. Before and during application of weatherproofing system
4. After completion of installation of full insulation system

The as-installed insulation system must not deviate from the designed thickness by more than +/-3mm.

6.6 Corrosion Prevention

In practice, water and moisture will penetrate into an insulation system. Particularly between -20°C and +175°C, or with cyclic operating temperatures, piping and equipment can be attacked by Corrosion Under Insulation (CUI), with the corrosion rate being a function of temperature, humidity, insulation material, insulation condition, and location of the installation.

Piping and equipment susceptible to CUI (as above) shall be designed such that ingress of water is prevented. The system required to protect the piping and equipment varies. A system selection diagram is provided in 7650-8440-SP-100-0002 to determine which surface coating is best suited for the specified operating conditions. The design requirements including surface preparation, coating system and thickness, application, and repairs are also specified and shall be adhered to.

As best practice to assist corrosion prevention, insulation materials shall be of the correct chemical nature and shall include the following requirements:

1. Carbon steels – Insulation to be chemically neutral or slightly alkaline

2. Aluminium – Insulation to be chemically neutral or slightly acidic
3. Stainless steels – Insulation shall be supplied in accordance with ASTM C-795

All insulated austenitic stainless-steel piping and equipment shall be protected against chloride attack with a sacrificial foil system, thermal spray aluminium, or a specific protective paint coating, as detailed in 7650-8440-SP-100-0002.

Because moist insulation systems can build up higher concentrations of corrosive components, paint systems fail sooner under insulation than non-covered paint systems; with most failing after 10 years – after which bare steel can be attacked by CUI. In addition to the inspection criteria defined in 6.5, an appropriate inspection and maintenance schedule must be developed to ensure than the integrity of the system remains appropriate through operational life, and any corrosion is detected early.

During the insulation design phase, to avoid condensation on cold insulation, the dewpoint shall be calculated using location specific information for ambient conditions and humidity detailed in the BEDD (document number 7650-8820-SP-100-0001) and then used in accordance with ISO-12241.

7. HOT SERVICE INSULATION

7.1 Design – General

Insulation comprises a layer of heat resisting material enclosed within a protective metal sheeting, sealed against the ingress of moisture and designed to allow differential thermal expansion.

Insulation is not necessary for piping and equipment for which heat loss is desired, other than for acoustic attenuation, personnel protection, or to avoid thermal stress problems.

Personnel protection is required for all exposed surfaces operating in excess of 60°C and located within 600mm horizontally or 2100mm vertically of a normal access, walkway, or work area. Piping and equipment designated for personnel protection shall be fully painted in accordance with 7650-8440-SP-100-0002.

The application of insulation shall take into account the expansion movements of piping and equipment under normal operating conditions. The design must allow for expansion joints using a calculated rate with **Table 3** providing a guidance to the supporting calculations:

Temperature	<200°C	200°C - 300°C	300°C - 400°C	>400°C
Expansion Joint Spacing	5 metres	4 metres	3 metres	2 metres

Table 3 – Temperature vs. Expansion Joint Spacing Intervals

Multi-layer construction is required when operating temperatures exceed 300°C and/or the insulation thickness exceeds 70mm, or less if specified by the supplier. Staggered joints shall be used, with each layer separately secured in place. Supports must be extended to provide support to each layer.

The equipment nameplate must remain visible after insulation has been applied. The surrounding areas shall be sufficiently sealed to prevent water ingress.

Flanges and other bolted connections shall be insulated except in the following instances:

1. When specifically requested for process requirements.
2. When specified by the unit licensor.
3. When connections may be subject to a cooling purge in operation/shutdown/emergency.
4. When a bolt material has been specified for a lower temperature than the design temperature of the connection.
5. When a bolt material has been specified which has a higher coefficient of thermal expansion than the flange material.

6. When the connection operates in creep service for the specified materials.
7. When a connection is required to transfer a high mechanical load – Subject to review by IPMT during design phase.

Insulation shall be in the form of boxes/covers and shall offer the same thickness of insulation as the attached piping/equipment. The boxes/covers shall be designed to be easily removed and reinstalled without damage to the assembly. The pieces of the assembly should have no sharp edges, and each component shall weigh less than 25kg.

The insulation locally shall be adequately weather proofed such that the flange bolts may be withdrawn, and unions broken without damage to the local insulation and it's weatherproofing.

Provision shall be made to permit the detection of flange leakage in the form of 'Flangebelts' with sniffer tubes. A 'Flangebelt' refers to a metallic band fitted over the flange joint, around the flange outside diameter. The purpose of the tube is to assist leak detection by providing a path to the flange joint from outside the insulation assembly. The 'Flangebelt' metallurgy must be appropriate for the flanges to which they are attached in terms of matched expansion coefficients. 'Flangebelts' shall only be used on hydrocarbon (fugitive emissions) and toxic service; and not on water, steam, nitrogen, air.

All details shall be in accordance with CINI, specific to the installation in question.

Piping and equipment internally lined with an insulating castable/gunned refractory shall not be externally insulated unless specially required for metal temperature control, e.g. to keep a skin temperature above dewpoint. If required, personnel protection should be achieved with the use of stood off metal guards.

7.2 Design – Materials

Materials to be used for hot service insulation are specified below. Alternative materials may be considered where deemed appropriate and/or necessary for the installation configuration in question. These should be reviewed by the appropriate engineering teams on a case-by-case basis. For Project One, approval by IPMT shall be required.

7.3 Mineral Wool / Rock Wool

Mineral fibre (Rockwool) is a fibrous pre-formed insulation (mineral fibre with resin binder), of long fibred rock material processed from a molten state into fibrous form and bonded with a binder suitable for the intended operating temperature range. The minimum requirements of ASTM C-547 and/or ASTM C-612 must be satisfied.

The insulating material shall conform to the physical requirements included in CINI for Rockwool (RW) slabs, excerpt below:

Density	120 kg/m^3 (nominal)						
Alkalinity PH	Min 7, max 10.5 (see ASTM C-871)						
Chloride Content	<20ppm (see ASTM C-795)						
Sodium plus Silicate Content	<40ppm (see ASTM C-795)						
Mean Temp (°C)	50	100	200	300	400	500	600
Max Conductivity 'k' (W/m.°C)	0.042	0.046	0.060	0.081	0.110	0.147	0.192

Table 4 – Hot service Insulation (RW) Mechanical Properties

Mineral wool / rock wool shall be a water repellent grade and conform to the conditions of testing in accordance with NBN EN-13472 / NBN EN ISO 29767.

Mineral wool flexible mattress shall be faced on one side with galvanised steel wire mesh having hexagonal spacing secured with galvanised steel stitching. At temperatures above 400°C and on

stainless steel piping and equipment, stainless steel wire mesh and stitching shall be used and on boiler tube banks with the exception of the boiler.

7.4 Alkaline Earth Silicate Wool

Silicate materials (e.g. Insulfrax, Superwool) shall only be used when there is no potential for water ingress to insulation. The silicate wool blankets are intended to be used in high temperature application range as first build up layers until temperature profile is down to 500°C, below normal mineral wools / rock wool as defined in 7.3.

7.5 Silica Aerogel

Silica aerogel is a lightweight solid with an extremely low density having several remarkable properties, most notably its effectiveness as a thermal and acoustic insulator. Aerogels (e.g. Pyrogel (XTE, XTF, HPS)) are very good alternatives with very wide temperature profiles and excellent performance in CUI defence; products can be used in combination for protection to pool and jet fire and cryogenic spill protection.

Suitable application for Aerogel products are:

- Flexible aerogel blanket material, compliant with ASTM C1728 type III grade 1A, is an acceptable alternative for insulation classes: H, P, A, B, C
- Flexible aerogel blanket material, compliant with ASTM C1728 type I grade 1B, is an acceptable alternative for insulation classes: G, A, B, C

The flexible Aerogel blanket materials referenced above where appropriate may be used in acoustical combination services detailed in 5.1.

7.6 Design – Piping Insulation

Insulated piping systems shall have straight pipe, bends, tees, and non-flanges pipe fittings completely insulated. Insulation shall be supplied, fabricated, and fitted by the insulation subcontractor, in accordance with CINI.

Insulation of piping shall be completed using rigid, pre-formed, sectional materials. Where pipe diameter is too large for moulded pipe sections, bevelled lags shall be used.

All bends, tees, and elbows shall be insulated with pre-forms of the same material and thickness as that used for straight piping, unless approved otherwise.

Where insulation is used for acoustic attenuation, Class B or C (per ISO 15665), the system shall be completely insulated including equipment items, valves, flanged joints, pipe fittings, and manways.

Insulation shall not be applied to the following unless otherwise specified for acoustic attenuation, personnel protection, or other special reasons:

1. Piping which becomes hot intermittently, such as relief valves, vents, steam-out and snuffing steam systems, flare and blowdown systems, and by-passes at control valves.
2. Supports for piping.
3. Steam traps (except bucket and float type which shall be traced and insulated together with the inlet piping).
4. Valves including control valves.
5. Pipe union fittings.
6. Thermowell bosses and pressure tappings.
7. Expansion joints, hinged joints, and hose assemblies.
8. Sight flow indicators.

Where insulated horizontal piping is supported on steel shoes, the height of the shoe shall be such that the underside of the insulation finishing material is clear of the supporting structure upon which the shoes rests, by a minimum of 50mm.

Insulation applied to vertical piping or lines inclined more than 45° from horizontal where straight runs are in excess of 3m shall be supported by bolted insulation supports. Supports shall be supplied, fabricated, and fitted by the insulation subcontractor, in accordance with CINI.

Drain holes with drain plugs shall be provided and shall be 8-10mm diameter and installed at all low points. A drain hole shall be provided at the bottom of all vertical sections of pipework and at the expansion joint on all horizontal sections. Drain holes to be drilled from the inside to the outside of the sheeting.

Where electric or steam tracing is specified, oversized insulating sections shall be used to accommodate both the parent pipe and tracer without damage or deformation of the insulation. Traced instrument lines and fittings shall be totally enclosed by the insulation in a similar manner. The designed warm air annulus shall be maintained throughout the traced length. The nominal pipe size used for selection of required insulation thickness shall take into consideration the oversizing required to accommodate the tracer. Protection of electrical tracing cable to be provided where damage by insulation sheeting is possible, e.g. by using grommets.

7.7 Design – Equipment

Insulation for vessels and similar equipment shall be adequately supported or suspended, dependant on insulation material form, with clips and support lugs, welded on by the equipment vendor at intervals around the equipment item and positioned in accordance with CINI.

Bottom heads of insulated vertical vessels fully enclosed by a support skirt shall be insulated without weatherproofing jacket finishing material. All bottom heads of insulated vertical vessels shall be insulated.

Support skirts of insulated vertical vessels greater than 1200mm diameter shall be insulated both internally and externally for a minimum of 600mm below the bottom tangent line. Support skirts of insulated vessels of 1200mm diameter and less shall be insulated externally only.

On skirts which do not require fireproofing, the insulation shall terminate not less than 300mm above the support concrete or steelwork. Where support skirts are to be fireproofed the insulation shall extend to the top of the fireproofed areas, and stainless-steel finishing material shall be used to protect the area of skirt insulation below the bottom tangent line.

Where the temperature at the support interface (underside of skirt/support) is calculated to be above 60°C, vessels and their skirts/supports shall be thermally isolated from their supporting surface (and hold-down bolts) using suitable insulating materials of such a thickness that the temperature at the interface is below the 60°C limit. The material and the configuration shall be subject to IPMT review and approval. The integrity of the thermal isolation material must include an assessment for shear induced during expansion movement as well as the compressive load.

External vacuum stiffening rings on equipment shall be fully and independently insulated. The insulation finishing material shall be sealed and allow for differential thermal expansion. The sheeting shall be shaped to naturally shed water.

Insulation shall not be applied to the following unless required for acoustic attenuation, personnel protection, fire hazard protection, or other special reasons:

1. Pumps with operating temperatures below 200°C unless pumped fluid has a pour point above minimum design ambient temperatures.
2. Fans, compressors, blowers, or other rotating or reciprocating equipment.
3. Surfaces of coolers and exchangers.
4. Nameplates on all equipment items.
5. Thermowell bosses and pressure tappings.

7.8 Hot service Insulation Thickness Tables

In this standard, insulation for the prevention of heat loss is designed to provide economic thicknesses such that heat loss from the system is limited to 200W/m^2 and the cold surface temperature shall not exceed 60°; whilst insulation for personnel protection is designed to insulate such that the resulting cold face surface temperatures do not exceed 60°C.

Table 5, Table 6, and Table 7 show minimum hot service insulation thicknesses required for Project One. The insulation thicknesses are calculated in accordance with the requirements of ISO-12241. The conductivities used in the calculations are based on the requirements included in CINI (2.2.01), so are manufacturer independent.

These two design parameters present the bounding cases for conditions at the site:

- Heat conservation insulation thicknesses are based on the coldest ambient expected combined with the highest operational wind speed.
- Personnel protection insulation thicknesses are based on the hottest ambient expected in still air.

Insulation thickness for equipment to be based on the outside diameter of the equipment, using the appropriate thickness (in **Table 5**, **Table 6**, and **Table 7**) up to 48” (1219mm) outside diameter, and ‘Flat’ for equipment with an outside diameter greater than 48” (1219mm).

7.8.1 Heat Conservation

Insulation Thickness Required for Heat Conservation (mm) using Mineral Fibre											
Pipe Size (in) Up to:	Internal Operating Temperature (°C)										
	Amb to 50	**51 to 100**	**101 to 150**	**151 to 200**	**201 to 250**	**251 to 300**	**301 to 350**	**351 to 400**	**401 to 450**	**451 to 500**	**501 to 550**
0.5	25	25	25	30	40	50	60	70	85	100	115
0.75	25	25	25	30	40	50	65	75	90	105	120
1	25	25	25	35	45	55	65	80	95	110	130
1.5	25	25	25	35	50	60	75	90	105	125	145
2	25	25	25	40	50	65	80	95	110	130	150
3	25	25	30	40	55	70	90	105	125	145	170
4	25	25	30	45	60	75	95	110	135	155	180
6	25	25	30	50	65	85	100	125	145	170	200
8	25	25	35	50	70	90	110	130	160	185	215
10	25	25	35	50	70	95	115	140	165	195	225
12	25	25	35	55	75	95	120	145	175	205	235
14	25	25	35	55	75	100	125	150	180	210	245
16	25	25	35	55	80	100	125	155	185	215	250
18	25	25	35	55	80	105	130	155	190	225	260
20	25	25	35	60	80	105	130	160	195	230	265
24	25	25	40	60	85	110	135	165	200	235	275
30	25	25	40	60	85	115	140	175	210	250	290
36	25	25	40	65	90	115	145	180	215	255	300
42	25	25	40	65	90	120	150	180	220	265	310
48	25	25	40	65	90	120	150	185	225	270	315
FLAT (>48")	25	25	50	80	115	150	190	240	295	360	425

Table 5 – Hot service Insulation Thickness – Mineral Wool Heat Conservation

Design Parameters:	Ambient Temperature: Wind Velocity: Conductivity: Insulation Finish Emissivity: Minimum Insulation Thickness: Heat Flow Limit: Maximum cold face temperature:	-5°C 3.5m/s RW from CINI (2.2.01) 0.1 (Oxidised Aluminium) 25mm 200W/m^2 60°C

	Insulation Thickness Required for Heat Conservation (mm) using Pyrogel												
Pipe Size (in) Up to:	Internal Operating Temperature (°C)												
	Amb to 50	**51 to 100**	**101 to 150**	**151 to 200**	**201 to 250**	**251 to 300**	**301 to 350**	**351 to 400**	**401 to 450**	**451 to 500**	**501 to 550**	**551 to 600**	**601 to 650**
	Pyrogel XTE							**Pyrogel HPS**					
0.5	5	10	10	10	15	15	15	20	20	20	20	20	20
0.75	5	10	10	15	15	15	15	20	20	20	20	20	20
1	5	10	10	15	15	15	20	20	20	20	20	20	20
1.5	5	10	15	15	15	20	20	20	20	30	30	30	30
2	5	10	15	15	20	20	20	30	30	30	30	30	30
3	5	10	15	15	20	25	25	30	30	30	30	40	40
4	10	10	20	20	20	30	30	30	30	40	40	40	40
6	10	10	20	20	30	30	30	40	40	40	40	50	50
8	10	10	20	20	30	30	40	40	40	50	50	50	50
10	10	10	20	20	30	30	40	40	40	50	50	60	60
12	10	10	20	20	30	30	40	40	50	50	60	60	60
14	10	10	20	20	30	30	40	40	50	50	60	60	70
16	10	10	20	20	30	40	40	50	50	50	60	60	70
18	10	10	20	20	30	40	40	50	50	60	60	70	70
20	10	10	20	20	30	40	40	50	50	60	60	70	70
24	10	10	20	30	30	40	40	50	50	60	70	70	80
30	10	10	20	30	30	40	40	50	60	60	70	80	80
36	10	10	20	30	30	40	50	50	60	70	70	80	90
42	10	10	20	30	30	40	50	50	60	70	80	80	90
48	10	10	20	30	30	40	50	50	60	70	80	80	90
FLAT (>48")	10	10	20	30	30	40	50	60	70	80	90	90	100

Table 6 - Hot service Insulation Thickness – Pyrogel Heat Conservation

Design Parameters:	Ambient Temperature: Wind Velocity: Insulation Finish Emissivity: Heat Flow Limit: Maximum cold face temperature:	-5°C 3.5m/s 0.1 (Oxidised Aluminium) 200W/m^2 60°C

7.8.2 Personnel Protection

Insulation Thickness Required for Personnel Protection (mm) using Mineral Fibre											
Pipe Size (in) Up to:	Internal Operating Temperature (°C)										
	Up to 60	**61 to 100**	**101 to 150**	**151 to 200**	**201 to 250**	**251 to 300**	**301 to 350**	**351 to 400**	**401 to 450**	**451 to 500**	**501 to 550**
0.5	Guard	Guard	Guard	30	40	50	60	70	85	100	115
0.75	Guard	Guard	Guard	30	40	50	65	75	90	105	120
1	Guard	Guard	Guard	35	45	55	65	80	95	110	130
1.5	Guard	Guard	Guard	35	50	60	75	90	105	125	145
2	Guard	Guard	Guard	40	50	65	80	95	110	130	150
3	Guard	Guard	Guard	40	55	70	90	105	125	145	170
4	Guard	Guard	Guard	45	60	75	95	110	135	155	180
6	Guard	Guard	Guard	50	65	85	100	125	145	170	200
8	Guard	Guard	Guard	50	70	90	110	130	160	185	215
10	Guard	Guard	Guard	50	70	95	115	140	165	195	225
12	Guard	Guard	Guard	55	75	95	120	145	175	205	235
14	Guard	Guard	Guard	55	75	100	125	150	180	210	245
16	Guard	Guard	Guard	55	80	100	125	155	185	215	250
18	Guard	Guard	Guard	55	80	105	130	155	190	225	260
20	Guard	Guard	Guard	60	80	105	130	160	195	230	265
24	Guard	Guard	Guard	60	85	110	135	165	200	235	275
30	Guard	Guard	Guard	60	85	115	140	175	210	250	290
36	Guard	Guard	Guard	65	90	115	145	180	215	255	300
42	Guard	Guard	Guard	65	90	120	150	180	220	265	*Guard
48	Guard	Guard	Guard	65	90	120	150	185	225	270	*Guard
FLAT (>48")	Guard	Guard	Guard	80	115	150	190	240	295	*Guard	*Guard

Table 7 – Hot service Insulation Thickness – Mineral Wool Personnel Protection

Design Parameters:	Ambient Temperature: Wind Velocity: Conductivity: Insulation Finish Emissivity: Minimum Insulation Thickness: Max Cold Face Surface Temp:	27.2°C 0.25m/s RW from CINI (2.2.01) 0.1 (Oxidised Aluminium) 25mm 60°C

*When insulation thickness to meet required surface temperature requirements are over 300mm, consider using barriers to remove the requirement, else consider other materials.

8. COLD SERVICE INSULATION

8.1 Design – General

The design of insulation systems, including the selection of adhesives, weather coatings, vapour seals, and joint sealers, shall take into account that piping and equipment may be subject to elevated temperatures during purging, cleaning, and flushing operations.

Personnel protection is required for all exposed surfaces operating below -10°C and located within 600mm horizontally or 2100mm vertically of a normal access, walkway, or work area. Piping and equipment designated for personnel protection shall be fully painted in accordance with 7650-8440-SP-100-0002.

Insulation contraction joints shall be provided for all equipment and piping where differential thermal movements exceed 15mm and shall be positioned under insulation layer support rings, clips, and lugs when they are used. Contraction joints shall be supplied, fabricated, and fitted by the insulation subcontractor, in accordance with CINI. As a minimum, contraction joints shall be installed at 5-6m intervals or between any fixed points more than 0.8m apart. Pipe spacing must also allow for the inclusion of contraction joints when included in parallel pipe runs.

A vapour barrier system is used to seal all piping and equipment against the ingress of moisture which shall be a fire-resistant mastic possessing good flexibility. The vapour barrier, sealants, and adhesives shall be supplied in accordance with CINI, and installed fully in accordance with the manufacturer's instructions. All installation design details shall be in accordance with CINI, specific to the installation in question. Where no appropriate detail exists in CINI, as a minimum, two coats of continuous membrane reinforced vapour barrier mastic should be included, applied to a nominal film thickness of 3mm, of composition detailed in 8.2.

The vapour barrier shall be applied prior to the installation of the weatherproof jacketing. Shop application of the vapour barrier to the insulating medium should be maximised. To ensure the vapour barrier is not punctured, when used, bands or fasteners shall be smooth and free of sharp edges.

Attachments and supports shall be insulated for a minimum of 200mm or 4x the insulation thickness, whichever is greatest beyond the main insulation.

Per Sections 8.7 and 8.9 all flanges in cold service shall be insulated. 'Flangebelts' and PTFE sniffer tubes shall be installed at all insulated flanged joints. A 'Flangebelt' refers to a stainless-steel band fitted over the flange joint, around the flange outside diameter. The purpose of the tube is to assist leak detection by providing a path to the flange joints. 'Flangebelts' shall only be used on hydrocarbon (fugitive emissions) and toxic service.

The insulation shall be installed over a nameplate without any break. The position of the nameplate shall be marked on the outer covering, and where a warning notice exists, this shall be copied onto the outside of the jacketing material. A duplicate nameplate shall be installed over the outside surface of the insulation system and fastened by the insulation applicator, in such a manner as to not puncture the vapour seal.

Multi-layer construction is required when the insulation thickness exceeds 50mm. Staggered joints shall be used, with the layers stepped by a minimum of 25mm, and each layer separately secured in place. Where multi-layer construction is used, secondary vapour barrier may also be required to further protect the insulation system.

All details shall be in accordance with CINI, specific to the installation in question.

8.2 Design – Materials

Materials to be used for cold service insulation are specified below. Alternative materials may be considered where deemed appropriate and/or necessary for the installation configuration in question. These should be reviewed by the appropriate engineering teams on a case-by-case basis. For Project One, approval by IPMT shall be required.

Insulation materials shall be water repellent, and impervious to water and steam.

8.3 Phenolic Foam

The use of phenolic foam is to be discouraged due to susceptibility to stress corrosion cracking causation and shall only be considered/used as rigid spray/pour foam for injection and in-situ forming with the formal approval of IPMT.

8.4 Poly-Iso-Cyanurate (PIR)

Polyisocyanurate (PIR) shall be used in slabs, sections, and segments.

PIR foam shall be protected against prolonged UV radiation and exposure to ambient weather.

The insulation material shall conform to the physical requirements included in CINI for PIR slabs, excerpt below:

Density	40 kg/m^3							
Alkalinity PH	Min 5.5, max 7.0 (see ASTM C-871)							
Water Details	Max 2% vol Absorption							
Expansion coefficient	Max. 70x10^{-6} m/m°.C							
Mean Temp (°C)	-180	-150	-100	-50	0	10	50	100
Max 'k' (W/m.°C)	0.016	0.017	0.022	0.026	0.029	0.029	0.033	0.038

Table 8 – Cold service Insulation (PIR) Mechanical Properties

8.5 Cellular Glass

Cellular glass shall be used in pre-formed or shaped condition.

Cellular glass shall be composed of hermetically sealed cells and shall be totally inorganic and contain no binders.

Cellular glass shall be used in dual temperature service. Where cellular glass is used on surfaces operating at more than 125°C it shall be supplied in two layers, bonded together with suitable cement and reinforced with a layer of glass cloth. Cellular glass is recommended under cryogenic conditions where there is high risk of CUI, e.g. cyclic operation.

A vapour barrier shall be applied to the cellular glass prior to the installation of the weatherproof jacketing. Vapour barriers shall be installed per manufacturer's instructions.

The insulation material shall conform to the physical requirements included in CINI for Cellular Class (CG) slabs, sections, and segments, excerpt below:

Density		115 kg/m^3								
Alkalinity PH		Min 7, max 10.5 (see ASTM C-871)								
Comp Strength		5 kg/cm^2								
Water Details		Zero Hygroscopicity, Permeability, Water Absorption, Capillarity								
Expansion coefficient		8.5x10^{-6} m/m°.C								
Mean Temp (°C)		-180	-150	-100	-50	0	50	100	200	300	430(1)
Max 'k' (W/m.°C)	Slab	0.020	0.022	0.027	0.035	0.040	0.048	0.057	0.079	0.103	0.142(1)
	Section	0.022	0.024	0.029	0.036	0.043	0.052	0.062	0.086	0.110	0.142(1)

Table 9 – Cold service Insulation (CG) Mechanical Properties

Note (1): Additional k value at 430°C included, data provided from CG supplier test data.

8.6 Foamed EPDM Rubber

The use of Armaflex HT or equivalent material approved by IPMT, is subject to prior approval by IPMT and shall only be proposed as follows:

- For sanitary piping up to 90°C.
- Instead of cellular glass to avoid destruction of that material due to shocks and vibrations, and where flexibility is required.
- Where flexibility is required.
- Pipe sizes up to 1½".

8.7 Silica Aerogel

Silica aerogel is a lightweight solid with an extremely low density having several remarkable properties, most notably its effectiveness as a thermal and acoustic insulator. Aerogels (e.g. Cryogel Z) are very good alternatives with very wide temperature profiles and excellent performance in CUI defence, products can be used in combination for protection to pool and jet fire and cryogenic spill protection.

Suitable applications for Aerogel products are:

- Flexible aerogel blanket material, compliant with ASTM C1728 type I grade 1B, is an acceptable alternative for insulation classes: G, A, B, C

The flexible Aerogel blanket materials referenced above where appropriate may be used in acoustical combination services detailed in 5.1.

8.8 Design – Piping Insulation

Each line shall be insulated as a single unit. Insulated piping systems shall be fully insulated, including all piping fittings and components, together with supports, piping and tubing of insulated instruments, drains, valves, and flanged joints. Valves shall be insulated up to the packing gland. Insulation shall be supplied, fabricated, and fitted by the insulation subcontractor, in accordance with CINI manual.

Pipe supports and hangers shall be attached to the outside of the insulation and shall not be in contact with the pipe. The design of the supports and hangers shall be in accordance with CINI & relevant IPMT Piping Standards.

Insulation shall not be applied to piping and piping components which become cold intermittently (i.e. blowdown or pump-out systems, drain or filling systems etc.) unless otherwise specified for acoustic attenuation, personnel protection, or other special reasons. Note that if said piping is connected to an insulated cold source, it shall be treated as a projection and insulated.

All metal protrusions through the insulation shall be insulated in accordance with CINI. Protruding metal parts include but are not limited to, pipe trunnion supports, pipe support clips, pipe hangers, uninsulated piping connections such as vents, sample connections, and uninsulated instrumentation.

Insulation applied to vertical piping or lines inclined more than 45° from horizontal where straight runs are in excess of 3m shall be supported by bolted insulation supports. Supports shall be supplied, fabricated, and fitted by the insulation subcontractor, in accordance with CINI.

Insulation support rings shall be of such a width that the inner layer(s) and one-half of the outer layer of the insulation shall be supported.

8.9 Design – Equipment

Equipment items requiring insulation shall be fully insulated including all nozzles, manways, bolted flanges, stiffening rings, and exchanger channels and bonnet flanges.

Insulation shall not be applied to pumps, fans, compressors, blowers, or other rotating or reciprocating equipment unless otherwise specified for acoustic attenuation, personnel protection, or other special purposes.

Skirts supporting vertical equipment shall be insulated inside and out, secured to inside of skirt using specified insulation adhesive, and supported by angle or plate supports. Insulation thickness shall be the same as for the main equipment and shall extend down the skirt a distance of 4x the insulation thickness from the junction with the bottom head, but not less than 300mm.

Where equipment is supported on metal saddles, the insulation shall be carried down the saddle to the junction of the saddle and the thermal isolation material. The vapour barrier shall continue down over the isolation material.

Where equipment is supported using attached support lugs resting on unattached structural steel members, the insulation shall be extended not less than 4x the insulation thickness in each direction, measured from the junction of equipment with support lug. Thickness of insulation over the support lugs shall be the same as the main equipment, whilst thickness over structural steel members shall be ½ that specified for the main equipment.

Where temperature at the support interface (underside of skirt/support) is calculated to be below -10°C, vessels and their skirts/supports shall be thermally isolated from their supporting surface (and hold-down bolts) using suitable insulating materials of such a thickness that the temperature at the interface is above the -10°C limit. The material and the configuration shall be subject to IPMT review and approval. The integrity of the thermal isolation material must include an assessment for shear induced during contraction movement as well as the compressive load.

Equipment support legs shall be insulated with insulation blocks as part of the equipment area. Insulation thickness along the leg shall be the same as for the main equipment and shall extend down the legs a distance of 4x the insulation thickness, measured from the leg/equipment junction. Spaces between flange and webs of structural members shall be filled with block cemented in place with specified insulation adhesive.

All attachments which are an integral part of the vessel, such as insulation support rings or stiffeners, shall be insulated. For multi-layer insulation systems the vessel attachments shall be insulated with 2/3 of the total insulation thickness rounded up to the nearest 10mm. For single layer insulation systems the attachments shall be insulated with full insulation thickness.

Cold insulated equipment shall have all metal projections provided with the vapour weather barrier material continued for a minimum of 150mm along the uninsulated metal.

8.10 Cold Service Insulation Thickness Tables

In this standard, insulation for the prevention of heat gain is designed to provide economic thicknesses such that heat gain is limited to 25W/m^{2}K. Condensation control is also a mandatory requirement; the design is such that the resulting cold face surface temperatures prevent the formation of condensation and possible icing.

Table 10 shows the minimum cold service insulation thicknesses required for Project One. The insulation thicknesses are calculated in accordance with the requirements of ISO-12241. The conductivities used in the calculations are based on the requirements included in CINI (2.7.01), so are manufacturer independent.

For condensation control, the surface temperature must be a minimum of 0.5°C above the calculated dewpoint, which is derived using the site specific BEDD humidity data.

Insulation thickness for equipment to be based on the outside diameter of the equipment, using the appropriate thickness (in Table 10 and Table 11) up to 48” (1219mm) outside diameter, and ‘Flat’ for equipment with an outside diameter greater than 48” (1219mm).

8.10.1 Prevention of Heat Gain & Condensation Control

Insulation Thickness Required for Prevention of Heat Gain (mm) using PIR									
Pipe Size (in) Up to:	Internal Operating Temperature (°C)								
	Amb to 0	**-1 to -20**	**-21 to -40**	**-41 to -60**	**-61 to -80**	**-81 to -100**	**-100 to -120**	**-121 to -140**	**-141 to -160**
0.5	25	30	45	55	65	75	85	95	105
0.75	25	30	45	60	70	85	95	100	110
1	25	30	50	60	75	85	100	105	115
1.5	25	35	55	70	85	100	110	120	130
2	25	35	55	75	90	105	115	130	140
3	25	40	65	85	100	115	130	145	155
4	25	45	65	90	105	125	140	150	165
6	25	45	75	95	115	135	155	170	180
8	25	50	80	105	125	145	165	180	195
10	25	50	80	110	130	155	175	190	205
12	25	55	85	110	135	160	180	200	215
14	25	55	85	115	140	165	185	205	220
16	25	55	90	120	145	170	190	210	230
18	25	55	90	120	150	175	195	215	235
20	25	55	90	125	150	180	200	220	240
24	25	60	95	125	155	185	210	230	250
30	25	60	100	130	165	195	220	240	260
36	25	60	100	135	170	200	225	250	270
42	25	65	105	140	175	205	235	265	280
48	25	65	105	140	175	210	240	265	285
FLAT (>48")	25	80	130	180	230	275	315	350	385

Table 10 – Cold service Insulation Thickness – PIR Heat Gain Prevention & Condensation Control (Most Stringent)

Design Parameters Heat Gain	Ambient Temperature: Wind Velocity: Conductivity: Insulation Finish Emissivity: Heat Gain Limit: Minimum Insulation Thickness:	27.2°C 0.25m/s PIR from CINI (2.7.01) 0.1 (Oxidised Aluminium) 25W/m^2 25mm
Design Parameters Condensation Control	Dry Bulb/Wet Bulb Temperature: Calculated Dewpoint/Humidity: Wind Velocity: Conductivity: Insulation Finish Emissivity: Minimum Insulation Thickness	10.8°C / 8.5°C 6.3°C (Cold face >6.8°C) / 73.7% 0.25m/s PIR from CINI (2.7.01) 0.1 (Oxidised Aluminium) 25mm

Insulation Thickness Required for Prevention of Heat Gain (mm) using Cryogel Z									
Pipe Size (in) Up to:	Internal Operating Temperature (°C)								
	Amb to 0	**-1 to -20**	**-21 to -40**	**-41 to -60**	**-61 to -80**	**-81 to -100**	**-100 to -120**	**-121 to -140**	**-141 to -160**
0.5	10	15	20	25	30	35	45	50	55
0.75	10	15	20	25	35	40	45	55	60
1	10	15	20	30	35	45	50	60	65
1.5	10	15	25	35	40	50	60	65	75
2	15	20	25	35	45	55	65	70	80
3	15	20	30	40	55	65	75	85	90
4	20	20	40	50	60	70	80	90	100
6	20	30	40	60	70	80	90	110	120
8	20	30	40	60	70	90	100	110	130
10	20	30	50	60	80	90	110	120	140
12	20	30	50	70	80	100	110	130	140
14	20	30	50	70	90	100	120	130	150
16	20	30	50	70	90	110	120	140	150
18	20	30	50	70	90	110	130	140	160
20	20	30	60	80	90	110	130	140	160
24	20	40	60	80	100	120	130	150	170
30	20	40	60	80	100	120	140	160	180
36	20	40	60	80	110	130	150	160	180
42	20	40	60	90	110	130	150	170	190
48	20	40	60	90	110	130	150	170	190
FLAT (>48")	20	40	60	90	120	140	160	180	200

Table 11 - **Cold service Insulation Thickness – Cryogel Z Heat Gain Prevention & Condensation Control (Most Stringent)**

Heat Gain Prevention	Ambient Temperature: Wind Velocity Insulation Finish Emissivity: Minimum Insulation Thickness: Heat Gain Limit:	27.2°C 0.25m/s 0.1 (Oxidised Aluminium) 25mm 25W/m^2
Condensation Control	Dry Bulb Temperature: Wet Bulb Temperature: Wind Velocity: Insulation Finish Emissivity: Minimum Insulation Thickness	10.8°C 8.5°C (→ Humidity: 73.7%) 0.25m/s 0.1 (Oxidised Aluminium) 25mm

8.11 Dual Insulation Thickness Tables

In this standard, dual service insulation is designed to provide economic Cellular Glass (CG) thicknesses covering a temperature of -160°C up to 450°C. The heat flow limit in the cold range is 25W/m^{2}K and 200W/m^{2}K in the hot range. Condensation control is also a mandatory requirement; the design is such that the resulting cold face surface temperatures prevent the formation of condensation and possible icing. In all cases the surface temperature shall not exceed 60°C.

Table 12 shows the minimum dual service system insulation thicknesses required for Project One. The insulation thicknesses are calculated in accordance with the requirements of ISO-12241. The conductivities used in the calculations are listed in Table 9.

These two design parameters present the bounding cases for conditions at the site:

- Heat conservation insulation thicknesses are based on the coldest ambient expected combined with the highest operational wind speed.
- Heat gain prevention insulation thicknesses are based on the hottest ambient expected combined with the highest operational wind speed.

Insulation thickness for equipment to be based on the outside diameter of the equipment, using the appropriate thickness (in

Table **12**) up to 48” (1219mm) outside diameter, and ‘Flat’ for equipment with an outside diameter greater than 48” (1219mm).

Pipe Size (in) Up to:	Internal Operating Temperature (°C)																
	-160 to -141	**-140 to -121**	**-120 to -101**	**-100 to 81**	**-80 to -61**	**-60 to -41**	**-40 to -21**	**-20 to -1**	**0 to 20**	**21 to 100**	**101 to 150**	**151 to 200**	**201 to 250**	**251 to 300**	**301 to 350**	**351 to 400**	**351 to 450**
0.5	135	125	115	105	90	75	60	40	30	25	25	35	50	65	80	95	115
0.75	140	130	120	110	95	80	60	45	30	25	25	40	55	50	85	100	120
1	150	140	130	115	100	85	65	45	30	25	25	40	55	70	90	105	125
1.5	165	155	140	125	110	90	70	50	35	25	30	45	60	80	95	115	140
2	175	160	150	135	115	95	75	50	35	25	30	45	65	60	100	125	145
3	190	180	165	145	130	105	80	55	35	25	35	50	70	90	110	135	160
4	205	190	175	155	135	115	90	55	35	25	35	55	75	95	120	145	170
6	225	210	190	170	150	125	95	60	40	25	40	60	80	105	130	160	190
8	240	225	205	185	160	130	100	65	40	25	40	60	85	80	140	170	200
10	255	235	215	195	165	140	105	70	40	25	40	65	90	85	145	180	210
12	255	235	215	195	165	140	105	70	40	25	40	65	90	90	145	180	210
14	270	250	230	205	180	145	110	70	40	25	40	65	95	125	155	190	225
16	270	250	230	205	180	145	110	70	40	25	40	65	95	125	155	190	225
18	285	265	240	215	185	155	115	75	45	25	45	70	100	130	165	200	240
20	295	270	250	220	190	160	120	75	45	25	45	70	100	100	165	205	245
24	305	285	260	230	200	165	125	80	45	25	45	75	105	100	175	210	255
30	320	295	270	240	210	170	130	80	45	25	45	75	105	105	180	220	265
36	335	310	280	250	215	175	130	80	45	25	50	75	110	145	185	230	275
42	345	320	290	260	220	180	135	85	45	25	50	80	110	145	190	235	285
48	350	325	295	260	225	185	140	85	45	25	50	80	115	155	195	240	290
FLAT (>48”)	480	440	400	350	295	240	175	105	45	25	60	100	145	195	250	315	390

Table 12 - Insulation Thickness for Prevention of Heat Gain and Loss in Dual Service using Cellular Glass

Design Parameters:

Heat Conservation	Ambient Temperature: Wind Velocity: Insulation Finish Emissivity: Heat Flow Limit: Cellular Glass Insulation	-5°C 3.5m/s 0.1 (Oxidised Aluminium) 200W/m^2 (Table 9)
Personnel Protection	Ambient Temperature: Wind Velocity: Insulation Finish Emissivity: Max Surface Temperature: Cellular Glass Insulation:	27.2°C 0.25m/s 0.1 (Oxidised Aluminium) 60^{o}C (Table 9)

Heat Gain Prevention	Ambient Temperature: Wind Velocity: Insulation Finish Emissivity: Heat Flow Limit: Cellular Glass Insulation:	27.2°C 3.5m/s 0.1 (Oxidised Aluminium) 25W/m^2 (Table 9)
Condensation Control	Ambient Temperature: Wind Velocity: Insulation Finish Emissivity: Dew Point/Relative Humidity: Cellular Glass Insulation:	10.8°C 0.25m/s 0.1 (Oxidised Aluminium) 6.3°C (Cold Face 6.8°C)/73.7% (Table 9)

9. ACOUSTIC INSULATION

9.1 General

Where acoustic insulation is required, a porous layer is included within the insulation system to absorb sound. This layer shall be a preformed semi-rigid mineral fibre. Three classes of acoustic insulation, A, B, and C are defined in accordance with ISO-15665. Installation details to be in accordance with CINI.

When Class A insulation is specified it is not necessary to fully enclose flange connections, valves, and manways.

When Class B or C insulation is specified the system shall completely enclose penetrations or attachments to the main body of the pipe using the same insulation system as that of the pipe. This typically includes items such as flanged connections, valves, pipe fittings, and manways.

Enclosures shall be designed in accordance with ISO-15665. Typical examples are shown in Annex C, Fig C.7, C.8, C.9, and C.10. Vibration isolation is required where steel structures are used to provide support. Typical examples are shown in Annex C, Fig C.4, and C.5. Anti-vibration seals may be required to prevent metal to metal contact. A typical example is shown in Annex C, Fig C.2.

In hot service, where no thermal insulation is required (heat loss desirable), the acoustic absorptive material may be applied directly to the piping or equipment, so long at its maximum service temperature is not exceeded.

An acoustic absorptive layer may be applied directly over existing thermal insulation without modification to the thermal system. Hangers or other supports shall also be covered with the absorptive material.

It is of extreme importance that acoustic insulation be protected from mechanical damage. Where cladding may be stepped on during operational use, separately supported steps must be provided. Applicator shall take whatever precautionary measures are required to prevent damage occurring during transportation and/or handling and lifting.

9.2 Acoustic Insulation Thickness Table

Class	Porous Layer Thk	Min Mass per Unit Area of Cladding	Thickness for Standard Metal Sheet
A	50 mm	4.5 kg/m^2	0.6 mm Steel Plate
B	100 mm	6.0 kg/m^2	0.8 mm Steel Plate
C	50 + 50 mm	5.0 + 5.0 kg/m^2	0.7 + 0.7 mm Steel Plate

Table 13 – Acoustic Insulation Thicknesses

Class C attenuation shall be achieved by sequentially applying two 50mm thick porous insulation layers and two 0.7mm thick sound barrier acoustic cladding layers.

9.3 Combining Acoustic and Thermal Insulation

Where insulation is required for thermal as well as for acoustic control, the total thickness required shall be developed as detailed in Sections 9.3.1 & 9.3.2.

Where appropriate, the thermal insulating properties of the absorptive layer may be utilised to minimise the overall insulation thickness.

Proprietary combined thermal/acoustic insulation systems may be considered, but are subject to approval by IPMT.

9.3.1 Hot service

1. Select the appropriate thermal insulation thickness from Table 5/Table 7.
2. Select the appropriate acoustic insulation system from Table 13.
3. Compare the required thermal thickness against the required acoustic thickness
4. If the thermal insulation thickness is greater than required for acoustic insulation, then no further action – Installation of damping layer may be required
5. If the acoustic insulation thickness is greater than required for thermal insulation, the additional thickness shall be added to the thermal insulation required
6. If a damping layer is required – Class C – this shall be applied a minimum of 50mm from the pipe outer surface. If the temperature at 50mm exceeds the service temperature for the damping layer, then this may be moved outward to suit

9.3.2 Cold service

1. Select the appropriate thermal insulation thickness from Table 10.
2. Select the appropriate acoustic insulation system from Table 13.
3. The full cold service insulation including vapour barrier, shall be applied.
4. The full acoustic insulation thickness shall then be applied on top of the cold service insulation, with an additional external vapour barrier.

10. FIREPROOFING

Fire proofing systems are applied to steel structures, supports, piping, valves, and equipment to provide protection against thermal load caused by fire, for a limited period only – usually a minimum of 2 hours to protect until firefighting services are available.

This specification is only relevant to fire proofing in combination with insulation materials; fireproofing of structural steel columns, beams, and other supports shall be in accordance with the relevant project standards. See 7650-8440-SP-100-0003.

Most insulations can be applied as combined insulation/fireproofing systems, provided that the lower fire resistance insulation material is protected by the outer layer of temperature resistant material, clad in stainless-steel jacketing. Unless otherwise specified in project specific piping or equipment specifications and standards, the details included in Table 14 shall apply.

Item	Min Thk	Material	Protective Finish
'FP' Spec'd Equipment	50 mm	Mineral Wool with Hydrocarbon Fire Certification applied in two layers. The use of cellular glass may also be appropriate dependant on operating condition.	Only stainless-steel sheeting secured with stainless-steel banding is acceptable

Table 14 – Fireproofing Insulation Summary

11. DOCUMENTATION

The insulation subcontractor shall submit, as a minimum, the following documents to Contractor and IPMT for review:

- Details of insulation materials and material safety datasheets
- Design calculations
- Insulation procedure(s)
- Handling and storage/preservation procedure
- Insulation general arrangement drawing(s)
- Insulation detail drawing(s)
- Insulation quality plan covering all the steps for design, installation and inspection
- Insulation inspection report